(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 712 500 B1

# (12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
**31.10.2001 Bulletin 2001/44**

(21) Application number: **94922190.7**

(22) Date of filing: **04.08.1994**

(51) Int Cl.[7]: **G02B 5/18, G02B 27/44, B44F 1/12, B42D 15/10, B42D 209/00**

(86) International application number:
**PCT/AU94/00441**

(87) International publication number:
**WO 95/04948 (16.02.1995 Gazette 1995/08)**

## (54) A DIFFRACTIVE DEVICE

DIFFRAKTIVES GERÄT

DISPOSITIF DE DIFFRACTION

(84) Designated Contracting States:
**AT BE CH DE DK ES FR GB GR IE IT LI LU MC NL PT SE**
Designated Extension States:
**LT SI**

(30) Priority: **06.08.1993 AU PM038793**
**10.09.1993 AU PM111293**
**07.04.1994 AU PM486794**

(43) Date of publication of application:
**22.05.1996 Bulletin 1996/21**

(60) Divisional application:
**96117655.9 / 0 766 103**

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Remarks:

- Divisional application 96117655.9 filed on 04/11/96.
- The file contains technical information submitted after the application was filed and not included in this specification



Printed by Jouve, 75001 PARIS (FR)

EP 0 712 500 B1

## Description

**[0001]** This invention relates to a diffractive device. It relates particularly to a diffractive device which, when illuminated by a light source, generates one or more diffraction effects which are observable from particular ranges of viewing angles around the device. The device may be used in a number of different applications, and it has particular applicability as an anti-forgery security device on banknotes, credit cards, cheques, share certificates and other similar documents.

**[0002]** Several different types of diffractive devices which, when illuminated, generate diffractive images, are known. Earlier types of diffractive devices, such as that disclosed in Australian Patent Application 19576/83, typically used parallel straight line gratings with fixed spatial frequency. A different early type of diffractive device is disclosed in European Patent Application EP-A 240 262. This consisted of a "white grating canvas" which could be made to carry a diffractive coloured image by blocking out or printing over selected portions of the surface.

**[0003]** In January 1988, an Australian ten dollar banknote was released featuring a diffractive image of Captain Cook. The diffractive grating used in the image was for the most part comprised of substantially continuous lines, and the shapes and configurations of the lines were determined according to optical catastrophe theory in order to generate fine detail in the diffractive image observed.

**[0004]** International patent application PCT/AU90/00395, the contents of which are incorporated herein by reference, discloses an alternative method for generating an optical diffraction image. In this case, the diffractive device is divided into a large number of small diffraction grating structures, each of which diffracts a beam of light which acts as a pixel, with the pixels combining to form an overall image. According to preferred aspects of the arrangement disclosed, the respective diffraction grating of each pixel comprises a plurality of reflective or transmissive grooves or lines which are usually curved across the pixel. Groove or line curvature determines both local image intensity (eg. shading) and local optical structure stability. Groove or line spacing in each pixel grating determines local colour properties, with non-primary colours generated by a pixel mixing. Average groove or line orientation determines movement or colour effects. The overall surface structure of each pixel grating is selected from a palette of different grating types having a limited number of distinct values of average curvature and average spacing.

**[0005]** An advantage of the use of pixel gratings in a diffractive device is that it permits the device to generate more than one diffraction image. European Patent Application EP-A 497 292 and Australian Patent Application 53729/90 provide examples of this. Some of the gratings can have diffractive surfaces with particular line spacing and orientation characteristics which contribute to the generation of an image viewable from a particular range of viewing angles, and other gratings have different surface characteristics contributing to the generation of a different image viewable from a different range of viewing angles. This result is much more difficult to achieve in a continuous grating diffractive device.

**[0006]** Another advantage of a pixel grating diffractive device is that it allows storage of picture information in a digital format. However, a predetermined surface area on the diffractive device must be set aside for each pixel, and this is not the most efficient way of storing picture information in a limited space. Accordingly, there is scope for a more efficient manner of storing picture information in a diffraction grating.

**[0007]** Moreover, in a pixel grating diffractive device, there are inevitable discontinuities between adjacent gratings. Diffraction effects occur in these discontinuities. It is normally possible to ensure these extraneous diffraction effects are small relative to the intentional diffraction effects generated by the diffractive device, but the extraneous diffraction effects are still detectable. It is desirable to reduce the extraneous diffraction effects.

**[0008]** According to the prior art, there is provided a diffractive device having a surface relief structure which, when illuminated by a light source, generates one or more diffraction images which are observable from particular ranges of viewing angles around the device, wherein at least part of the surface relief structure is arranged in a series of tracks, each track having a surface relief structure comprised of individual structure elements, the surface relief structure being substantially continuous within the track, but substantially discontinuous with adjoining tracks, wherein "continuous" means that there are no substantial differences between adjacent structure elements in terms of orientation curvature and spacing, each track being greater than 0.5mm in length, each track having a diffracting surface component which generates a component of a diffraction image, such that at least one of the diffraction images generated by the diffractive device is formed from image components generated by a plurality of the tracks.

**[0009]** According to the present invention, there is provided a diffractive device as defined in claim 1.

**[0010]** Tracks may be of any suitable shape, size and configuration. The individual tracks have a length greater than 0.5mm. A width of 0.25mm represents approximately the limit of resolution of the human eye when viewing a diffractive device from close quarters, so that a track having a width of less than 0.25mm is unlikely to be separately discernible to the human eye.

**[0011]** The tracks may be in any suitable configuration. In one preferred arrangement, the tracks are straight and parallel, in side-by-side configuration. In an alternative arrangement, the tracks may form arcs of concentric circles. In other arrangements, the tracks may be in the shape of curving lines.

**[0012]** All of the tracks may generate a component of the same diffraction image, but it is preferred that the tracks be used to generate two or more different images. In one arrangement in which two diffraction effects or images are

generated, every second track contributes to one effect or image and every other track contributes to the other effect or image. It is not essential that all tracks be of the same width, but that is a preferred feature. It is not essential that the tracks for the two effects or images be arranged alternately; they may occur in any order. There may be more than two types of tracks, which may be associated with more than two effects or images.

**[0013]** In one preferred arrangement, the diffracting surface of each track comprises a series of lines or grooves which extend across the width of the track. As an alternative to lines or grooves, it is possible to use circles, polygons and other shapes which are capable of providing the required diffraction effects. In another preferred arrangement, the diffracting surface comprises a pattern of parallelogram-shaped indentations.

**[0014]** In another preferred arrangement, the diffracting surface of each track comprises a series of lines or grooves which extend in a generally lengthwise direction along the track. Such lines or grooves may be straight or curved, and in one arrangement they may be undulating periodically in a sinusoidal configuration. The lines or grooves may be short and discrete, or they may be substantially continuous throughout the length of the track.

**[0015]** In an especially preferred arrangement, the surface relief structure may include tracks having crosswise grooves or parallelogram patterns interspersed with tracks having lengthwise grooves or parallelogram patterns, such that diffraction effects from one set of tracks are observable when the diffractive device is viewed in the direction of the tracks, and diffraction effects from another set of tracks are observable when the diffractive device is viewed perpendicular to the direction of the tracks.

**[0016]** As an optional refinement, one of the images generated by the diffracting tracks may be a uniform or blank image which can be encoded with image information by the physical destruction or modification of regions of diffracting surface on selected tracks to produce corresponding diffusely reflecting regions.

**[0017]** The invention will hereinafter be described in greater detail by reference to the attached drawings which show an example form of the invention. It is to be understood that the particularity of the drawings does not supersede the generality of the preceding description of the invention.

**[0018]** Figure 1 is a schematic representation of a region of a surface relief structure on a diffractive device according to one example useful for understanding the invention.

**[0019]** Figure 2 is a schematic representation of parts of the surface relief structure of Figure 1.

**[0020]** Figure 3 is a schematic representation of other parts of the surface relief structure of Figure 1.

**[0021]** Figure 4 is a more detailed schematic representation of two parts of tracks used in a diffractive device according to an embodiment of the present invention.

**[0022]** Figure 5 is a detailed schematic representation of a part of two adjacent tracks in an alternative embodiment of the invention.

**[0023]** Figure 6 shows a schematic representation of a part of a track according to another embodiment of the invention.

**[0024]** Figure 7 shows a schematic representation of a part of two adjacent tracks according to an embodiment of the invention.

**[0025]** Figure 8 shows a computer-generated detailed representation of a section of two adjacent tracks according to an embodiment of the type shown in Figure 4.

**[0026]** Figure 9 shows a computer-generated detailed representation of a region of surface relief diffractive structure showing several tracks according to an embodiment of the type shown in Figure 5.

**[0027]** Figure 10 is a computer-generated detailed representation of a part of two adjacent tracks according to another embodiment of the invention.

**[0028]** Figure 11 is a computer-generated detailed representation of part of two adjacent tracks according to another embodiment of the invention.

**[0029]** Referring firstly to Figure 1, part 1 of the surface relief structure is arranged in a series of tracks 2, each track having a diffracting surface 3 which generates a component of a diffraction image. In the example illustrated, two separate images are generated, one by left hand side tracks 4, and one by right hand side tracks 5. The two diffraction images are formed from image components generated by individual tracks 4 and individual tracks 5 respectively.

**[0030]** Each of tracks 2 may be of any suitable length. It is preferred that each track be greater than 0.5mm in length, and for the sake of convenience, it is preferred that each track extend throughout the length of the diffractive device, although there is no requirement that this be the case. In the example illustrated, each of tracks 2 is straight and arranged in parallel side-by-side configuration. In alternative examples, the tracks may be arranged in concentric circles or sections of concentric circles, or in many other curved arrangements.

**[0031]** Each of tracks 2 may be of any suitable width. It is preferred that the tracks be sufficiently narrow to be not noticeable to the naked human eye. The limit of resolution of a normal human eye examining a diffractive device at close quarters is about 0.25mm. Accordingly, tracks having a width of less than this amount are unlikely to be separately discernible to the human eye.

**[0032]** As stated previously, discontinuities around the borders of individual pixels in pixellated diffracting devices result in incidental diffractive effects. The extent of such incidental effects is diminished by the use of tracks according

to the present invention in that discontinuities along the length of the track can be avoided, although discontinuities are still present along the sides of each track.

**[0033]** It is preferred although not essential that each of tracks 2 be of the same width. If each track has the same width, the encoding of diffraction image data in the diffracting surface of each track is a simpler operation. However, in situations where it is desired that the diffractive device generate multiple diffraction images, it may be desired that one such diffraction image be brighter than another, and one way of achieving such an effect is to devote wider tracks to the generation of the bright image and narrower tracks to the generation of the dull image.

**[0034]** In the example illustrated in Figure 1, tracks 2 are arranged substantially in side-by-side configuration. However, it is not essential that each track abut the next track, and a channel of any desired width may be left between adjacent tracks. It is sometimes advantageous to leave a small channel of about 4 micron in width between adjoining tracks to act as an air ventilation route during production of the diffractive device. Diffractive devices of the type herein described are typically manufactured by an embossing process, and it has been found that more satisfactory results are achieved if air ventilation can occur.

**[0035]** The diffracting surface on each of tracks 2 may have any suitable diffractive surface relief structure. In the example illustrated in Figures 1 to 3, the surface relief structure comprises a series of curved or straight lines or grooves which extend across the width of the track. It is not essential that lines be used, and other suitable diffractive shapes include circles and polygons. In one suitable arrangement, the surface relief structure of a track may consist of variably shaped polygon structures having dimensions less than 1 micron positioned along and across each track in such a way as to encode the diffraction image information and diffractively regenerate it. In another example, the surface relief structure of a track may consist of numerous diffracting dots of sizes less than 0.25 micron, such that the diffraction image information is encoded in the spacing and distribution of the dots.

**[0036]** Figure 4 illustrates in more detail portions of two tracks, each consisting of a complex generalized diffraction grating structure having grooves which vary continuously in terms of spacing, orientation and curvature along the length of the track. The variations in groove spacing, curvature and orientation are the means by which the diffraction image information is encoded in the tracks. In preferred arrangements, the variations in groove spacing, angle and curvature can be described by mathematical functions of two variables whose Hessian of second derivatives with respect to the two variables is non-vanishing except along certain characteristic lines within each diffracting track.

**[0037]** One particular example of a suitable track grating function is given by the following expression:

$$Y = (\alpha - 2\pi(1.25\beta))Z - \left(\frac{\beta}{\alpha - 2\pi(1.25\beta)}\right)\cos(2\pi X)\cos(2\pi[\alpha - 2\pi(1.25\beta)]Z) \qquad (1)$$

where:

- Z is the track groove index parameter;
- $\alpha = \alpha(Y)$ along the length of the track;
- $\beta = \beta(Y)$ along the length of the track;
- $\alpha$ is a preset variable which determines the local carrier wave frequency of the track and therefore determines the local line density of the track and the colour of the image component generated by the track. Typically, $0.8 < \alpha < 1.2$;
- $\beta$ is a parameter which is set proportional to the local intensity of the colour of the track and determines the structural stability of the track. It is this parameter that is used to tune the image characteristics of the diffractive device. Typically, $0 \leq \beta \leq 0.056$;
- the number ranges of the local co-ordinates X and Y is given by $0 \leq X \leq 0.2$ and $0.2 \leq Y \leq 0.6$ for a left hand channel track, and $0.6 \leq X \leq 0.8$ and $0.2 \leq Y \leq 0.6$ for a right hand channel track; and
- the Hessian of the track grating is non-vanishing except along certain characteristic lines of the grating plane which, under gradient transformations, map to lines of singularity (caustics) in diffraction space. The Hessian, H(X,Y) of Z(X,Y) is a standard complex derivative given by:

$$H(X,Y) = \frac{\partial^2 Z(X,Y)}{\partial X^2} \cdot \frac{\partial^2 Z(X,Y)}{\partial Y^2} - \left[\frac{\partial^2 Z(X,Y)}{\partial X \partial Y}\right]^2 \qquad (2)$$

[0038] Figure 4 shows two track segments having track grating functions of the type described in Equation (1) above. A single track may be comprised of several such segments linked end to end, each segment being of fixed or variable length. In arrangements where each track segment is of fixed length, it is preferred that each segment form a "period" in a "carrier wave" encoded into the track, with diffraction image information being encoded into each period by means of variation in groove spacing and curvature. The track segments illustrated in Figure 4 have a width of about 15 micron and a length of about 30 micron, although they can be scaled up or down in size as required.

[0039] Figure 5 is a computer-generated representation of a section of a pair of adjacent tracks, labelled 14 (left hand track) 15 (right hand track)channel. The track sections illustrated form part of a larger structure containing several left hand tracks interspersed between several right hand tracks. The left hand tracks, when illuminated, generate one or more diffraction images observable from particular positions around the diffractive device, and the right hand tracks generate images observable from different positions. The track portions illustrated are each about 15 micron in width and 60 micron in length.

[0040] As will be seen from close examination of Figure 8, each curved groove extending across the track is for the sake of convenience composed of eight segments 18, each of which is a parallelogram in shape. Each parallelogram indentation 18 is approximately two microns wide. Although most parallelograms 18 match up with neighbouring parallelograms to form curved grooves extending across the track, some add density to particular parts of the track surface without joining up with any neighbours.

[0041] The concept of dividing each groove into eight parallelograms 18 is taken a step further in the embodiment shown in Figure 10. In this embodiment, the track surface is comprised entirely of parallelogram-shaped indentations. The dark portions represent troughs, whereas the light portions represent crests. Some parallelograms match up with their neighbours to form grooves, but this is incidental rather than intentional as in the embodiment of Figure 8. In any line across one of the tracks in the embodiment of Figure 10, all parallelograms have the same angular orientation; whereas such orientation varies considerably in the embodiment of Figure 8.

[0042] The patterns shown in both Figure 8 and Figure 10 are used to generate pixels in the image planes. Each of the left-hand 14 and right-hand tracks 15 in each case includes two segments (16,17), the top half 17 being one segment and the bottom half 16 being another. Each segment generates one pixel. The patterns shown are used to generate pixels having one of sixteen different greyscale values. Segments with flatter lines produce darker pixels in the image plane, and segments with steeper lines (more sharply angled parallelograms) produce lighter pixels. A large number of track segments from different tracks can thus be used to generate a complete image with sixteen greyscales.

[0043] In addition to the 16 different types of greyscale segments, the "palette" of different track segment types in a preferred arrangement includes 10 different colour effects segments. The left hand track 14 in Figure 11 contains two colour effects segments (16,17). In the embodiment illustrated, colour effects segments are created using straight grooves which cross the track at right angles, with varying spatial frequencies. The right hand track 15 in Figure 11 contains two more colour effects segments, but with grooves aligned with the track to create "90° effects" - that is, diffractive effects which are visible at positions 90° around from where the left hand track diffractive effects are visible.

[0044] An especially desirable type of colour effect is obtained when the colours appear to move along a path in the image plane when the diffractive device is tilted about an axis in its plane. Such effects can be obtained by sequential positioning of colour effects track segment types, with average spatial frequency increasing or decreasing along the sequence.

[0045] It is preferred that the colour effects track segments be modulated so that image components generated by those segments are observable over broader ranges of angles than they would have been if their diffracting surfaces were unmodulated. A suitable general modulation function is given by:

$$y = ma + \beta F\left(Qs\frac{m}{N}\right)$$

where β is a modulation factor; a is the average diffraction structure spacing; Q is the number of cycles of modulation; N is the total number of grooves or equivalent diffraction structures within the track segment; m is the groove index parameter (m = 1 to N); and F is sin or cos or another harmonic or quadratic function.

[0046] The spatial frequency of the vertical grooves of the right hand track in Figure 11 is the same at the top and bottom of each segment, and changes through several steps to a characteristic frequency in the centre 19 of each segment.

[0047] The right hand track 15 in Figure 10 has a different average spacial frequency from the left hand track 14 in order to reduce the likelihood of interference between the two different images which are to be generated. Moreover, the parallelograms 18 in the left and right tracks have opposing angular orientations.

[0048] Track surface patterns of the types illustrated in Figures 8, 10 and 11 are typically created using an electron beam. A 30 micron by 30 micron surface area is typically divided into a grid of 1024 by 1024 units. This grid is then used to define the start and end points of each parallelogram. In the embodiments shown in Figures 8, 10 and 11, one

grid area covers one track segment (30 micron long) in each of two adjacent tracks (15 micron wide each). An algorithm, written in BASIC programming language, for generating the left hand track in Figure 10 is given by:

```
J1M&=JOM&+INT((45-3*(JJ-11))*ABS(SIN(1.5708*LLL/512))
*ABS(256-XINC)/1024)^1.5
J 1P&=JOP&+INT((45-3*(JJ-11))*ABS(SIN(1.5708*LLL/512))
*ABS(256-XINC)/1024)^1.5
```

where:

JOP is the top left corner of a parallelogram.
JOM is the bottom left corner
JIP is the top right corner
JIM is the bottom right corner
JJ is the number representing the type of greyscale element (JJ is between 11 and 26, giving 16 different types)
XINC = 64 (i.e. the width of the parallelogram, in grid positions)
LLL is a vertical index.

**[0049]** A similar algorithm applies for the right hand track in Figure 10.

**[0050]** The diffracting tracks illustrated in Figures 8, 10 and 11 contain digitally encoded image information. That is, tracks are divided into segments of a predetermined size, and a portion of image information (usually corresponding with a single pixel in the image plane) is stored in each segment. It is not however necessary that tracks be divided into regular segments. Instead, the diffractive surfaces may vary continuously but irregularly in terms of diffractive structure spacing, curvature and orientation, so that image information can be stored in an analogue format rather than a digital format. In such an arrangement, the image in the image plane may be comprised of a group of lines (each line corresponding to a track) rather than a group of discrete pixels (each pixel corresponding to one or more track segments).

**[0051]** One or more of the diffracting tracks may contain diffusely reflecting regions (consisting of randomly spaced grooves) and/or specularly reflecting regions in between diffracting regions. Diffusely reflecting regions may be used to encode auxiliary information not found in the diffraction image. Specularly reflecting regions may be used to enhance the contrast properties of the diffracted image.

**[0052]** One or more diffraction images which are generated by the diffracting tracks may consist of abstract colour patterns which create variable colour effects which move along the tracks when the device is moved relative to the light source and the observer. In particular, the movement effect may be generated when the device is rotated about an axis in its own plane.

**[0053]** It is preferred that the diffracting tracks generate two or more diffraction images which are observable from different ranges of viewing angles around the diffractive device, with some of the diffracting tracks being devoted to producing each of the diffraction images. In the example illustrated in Figures 1, 2 and 3, left hand tracks 4 are devoted to generating a first diffraction image which is observable from a first range of viewing angles around the diffractive device, and right hand side tracks 5 are devoted to generating a second diffraction image which is observable from a second range of viewing angles around the diffractive device. As illustrated in Figure 1, the tracks are in an alternating right-left-right-left configuration; however, this is not necessary and the tracks may be arranged in any order, such as right-right-left-right-left-left.

**[0054]** Figure 5 shows sections of two tracks according to another embodiment of the invention. Left hand track 6 has grooves extending across the width of the track, generating diffractive images which can be observed from a direction generally along the length of the track. Right hand track 7 consists of a plurality of island regions 8 surrounded by flat regions 9. Island regions 8 have grooves extending lengthwise along the track, generating diffractive images which can be observed from a direction generally perpendicular to the length of the track. A particular advantage of the arrangement illustrated in Figure 5 is that diffraction images are generated both in the direction of the length of the tracks and in the perpendicular direction, so that the diffractive effects of the diffractive device are more readily observable.

**[0055]** Flat regions 9 are optional, but they provide certain advantages. As previously indicated, diffractive devices of the type described are typically created using an embossing process, and flat regions 9 act as vents for gas removal during the embossing process, resulting in a more precise finished product. Moreover, an electroplating process typically follows the embossing process, and flat regions 9 enable more accurate electroplating. Flat regions 9 may also carry printed lines which are responsive to the scan rates of particular colour photocopiers so that moire interference lines are created on a photocopies image of the diffractive device. Alternatively or additionally, flat regions 9 may be embossed or printed with micro-writing 13 having a size in the order of 2 micron as shown in Figure 9. Such micro-writing may serve as an additional security element and may include a registration number or other identifier unique to the diffractive device on which it appears, thereby enabling verification of authenticity by means of microscopic

examination.

**[0056]** Left hand track 7, islands 8 and flat regions 9 may be of any suitable dimensions. In an especially preferred arrangement, left hand track 7 and island regions 8 are each about 15 micron in width, and flat regions 9 are about 4 micron in width.

**[0057]** In a variation on the arrangement shown in Figure 5, each island 8 may be connected to its neighbouring islands by means of interconnecting grooves which may be branched, so that grooves are substantially continuous throughout the length of the track.

**[0058]** Figure 6 shows a track 10 having grooves which extend substantially along the length of the track rather than substantially across the track as is the case in the track segments of Figure 4. The diffraction effects generated by track 10 are substantially at right angles to those generated by a track comprised of track segments of the type shown in Figure 4. Track 10 essentially comprises "carrier waves", with image information being encoded into them by means of amplitude and groove spacing variations.

**[0059]** In some embodiments, the variations in groove spacing, angle and curvature can be described by mathematical functions of two variables whose Hessian of second derivatives with respect to the two variables is non-vanishing except along certain characteristic lines within each diffracting track, as previously discussed. However, this is not an essential condition, and in other embodiments the Hessian of second derivatives of the grating function may be identically zero for all points within the track.

**[0060]** Figure 7 illustrates schematically a combination of left and right tracks, 11 and 12 respectively. Left track 11 may be any one of the types of tracks illustrated in Figures 1, 2, 3, 4 and 8 and right track 12 is a track of the type shown in Figure 6. Several such left and right tracks may combine to form a two-channel diffractive device. Tracks 11 and 12 may be of any suitable width as previously discussed, and an especially preferred width is around 15 micron. The arrangement illustrated in Figure 7 is particularly advantageous because the image(s) produced by left tracks 11 will be observable from angles approximately 90° around from where the image(s) generated by right tracks 12 are observable.

**[0061]** In one embodiment of the invention, one or more of the images generated by the diffractive device may consist of a uniform or blank image plane which can be encoded with image information by the destruction or modification of diffracting elements at selected locations along selected diffraction tracks. This enables post-production modification of the diffracting device to incorporate a new diffraction image, although the resolution of the image information so incorporated is lower than the resolution normally provided by a diffracting track. A particular embodiment of this feature comprises a series of tracks. Along the length of each track, the diffracting surface alternates between surface portions which give rise to black image components in the image plane and surface portions which give rise to white image components. In order to create a dark area in the image plane, the "white" parts of the corresponding diffracting surface portions are erased; whereas the "black" surface portions are erased to create a bright area. In this way it is possible to encode a black-and-white bit image into the tracks.

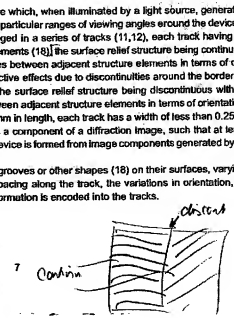
**[0062]** As a further enhancement, the diffracting surfaces on some of the tracks may include diffusely reflecting regions. Such regions do not effect the images observed in the image phase, but they give a neutral background appearance to the diffractive device, making the images more easily observable.

**[0063]** As another enhancement, some of the tracks may include specularly reflecting regions. Such regions are useful in adding contrast to the images observed in the image planes.

## Claims

1. A diffractive device having a surface relief structure which, when illuminated by a light source, generates one or more diffraction images which are observable from particular ranges of viewing angles around the device, wherein at least part of the surface relief structure is arranged in a series of tracks (11,12), each track having a surface relief structure comprised of individual structure elements (18), the surface relief structure being continuous within the track in that there are no substantial differences between adjacent structure elements in terms of orientation curvature and spacing and so that incidental diffractive effects due to discontinuities around the border of a track are diminished along the length of the track but the surface relief structure being discontinuous with adjoining tracks in that there are substantial differences between adjacent structure elements in terms of orientation, curvature or spacing, each track being greater than 0.5mm in length, each track has a width of less than 0.25mm, each track having a diffracting surface which generates a component of a diffraction image, such that at least one of the diffraction images generated by the diffractive device is formed from image components generated by a plurality of the tracks, and wherein

   at least some of said tracks have diffracting grooves or other shapes (18) on their surfaces, varying continuously in terms of orientation, curveture and/or spacing along the track, the variations in orientation, curvature and/or spacing being a means by which image information is encoded into the tracks.



2. A diffractive device according to claim 1 wherein the tracks are straight and parallel.

3. A diffractive device according to claim 1 wherein the tracks form areas of concentric circles.

4. A diffractive device according to claim 1 wherein the tracks are in the shape of curving lines.

5. A diffractive device according to any one of claims 1 to 4 wherein a region of the surface relief structure generates two different diffraction images observable from different ranges of viewing angles, and a first group of tracks on the region generate one of the diffraction images, and a second group of tracks interspersed with the first group generate the other diffraction image.

6. A diffractive device according to any one of claims 1 to 5 wherein on some tracks (11) the diffracting surface comprises a series of grooves oriented generally across the track and on some tracks (12) the diffracting surface comprises a series of grooves oriented generally along the track.

7. A diffractive device according to any one of claims 1 to 6 which includes tracks (10) which have grooves undulating periodically generally lengthwise of the tracks.

8. A diffractive device according to any one of claims 1 to 7 which includes tracks (7) whose diffracting surface comprises islands (8) which have grooves extending generally lengthwise of the track, the islands being surrounded by flat regions (9).

9. A diffractive device according to claim 8 wherein the flat regions are embossed or printed with microwriting (13).

10. A diffractive device according to any one of claims 1 to 9 wherein an image generated by the device is a uniform or blank image which can be encoded with image information by the physical destruction or modification of regions of diffracting surface on selected tracks to produce corresponding diffusely reflecting regions.

11. A diffractive device according to any one of claims 1 to 10 wherein on some tracks the diffracting surface comprises a pattern of parallelograms (18) of varying angular orientations, indented into the track surface.

12. A diffractive device according to any one of claims 1 to 11 wherein parts of the diffracting surfaces on some tracks are assigned to generating greyscale image information in the image plane.

13. A diffractive device according to any one of claims 1 to 12 wherein parts of the diffracting surfaces on some tracks are assigned to generating colour effects in the image plane.

14. A diffractive device according to claim 13 wherein the colour effects appear to move along a path in the image plane when the device is tilted about an axis in its own plane.

15. A diffractive device according to any one of claims 1 to 14 wherein image information from an image generated by the device is encoded in an analogue manner along the length of some tracks, each track generating a line of the image, the lines generated by those tracks combining to form the image.

16. A diffractive device according to any one of claims 1 to 15 wherein image information from an image generated by the device is encoded in a digital manner along the length of some tracks, each track generating a line of the image, the lines generated by those tracks combining to form the image.

17. A diffractive device according to any one of claims 1 to 16 wherein some tracks include diffusely reflecting regions.

18. A diffractive device according to any one of claims 1 to 17 wherein some of the tracks include specularly reflecting regions.

19. A diffractive device according to any one of claims 1 to 18 wherein the variations in orientation, curvature and spacing can be described by mathematical functions of two variables in which the Hessian of second derivatives is non-vanishing except along certain characteristic lines within each track.

Patentansprüche

1. Eine diffraktive Vorrichtung mit einer Oberflächenreliefstruktur, die bei Beleuchtung durch eine Lichtquelle ein oder mehr Beugungsbilder erzeugt, die aus unterschiedlichen Betrachtungswinkelbereichen um die Vorrichtung beobachtbar sind, wobei wenigstens ein Teil der Oberflächenreliefstruktur in einer Reihe von Bahnen (11, 12) angeordnet ist, wobei jede Bahn eine Oberflächenreliefstruktur aufweist, die aus einzelnen Strukturelementen (18) besteht, ferner die Oberflächenreliefstruktur innerhalb der Bahn kontinuierlich ist, indem dort keine wesentlichen Unterschiede zwischen aneinandergrenzenden Strukturelementen hinsichtlich Orientierung, Krümmung und Beabstandung bestehen und so daß zufällige Beugungseffekte aufgrund von Diskontinuitäten um die Grenze einer Bahn herum entlang der Länge der Bahn verringert werden, aber die Oberflächenreliefstruktur diskontinuierlich mit aneinandergrenzenden Bahnen ist, indem dort wesentliche Unterschiede zwischen aneinandergrenzenden Strukturelementen hinsichtlich Orientierung, Krümmung oder Beabstandung bestehen, wobei jede Bahn mehr als 0,5 mm lang ist und weniger als 0,25 mm breit ist und jede Bahn eine beugende Oberfläche aufweist, die eine Komponente eines Beugungsbildes erzeugt, so daß wenigstens eines der von der diffraktiven Vorrichtung erzeugten Beugungsbilder aus von mehreren Bahnen erzeugten Bildkomponenten gebildet wird, und wobei wenigstens einige der Bahnen beugende Kerben oder andere Gestalten (18) auf deren Oberflächen aufweisen, die hinsichtlich Orientierung, Krümmung und/oder Beabstandung entlang der Bahn variieren, wobei die Variationen hinsichtlich der Orientierung, Krümmung und/oder Beabstandung ein Mittel sind, durch das Bildinformation in den Bahnen verschlüsselt ist.

2. Eine diffraktive Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet,** daß die Bahnen geradlinig und parallel sind.

3. Eine diffraktive Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet,** daß die Bahnen Gebiete aus konzentrischen Kreisen bilden.

4. Eine diffraktive Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet,** daß die Bahnen in Gestalt von schwebenden Linien vorliegen.

5. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 4, **dadurch gekennzeichnet,** daß ein Gebiet der Oberflächenreliefstruktur zwei unterschiedliche Beugungsbilder erzeugt, die unter unterschiedlichen Betrachtungswinkelbereichen beobachtbar sind, und eine erste Gruppe von Bahnen auf dem Gebiet eines der Beugungsbilder erzeugt, und eine zweite Gruppe von Bahnen mit der ersten Gruppe dazwischen das andere Beugungsbild erzeugt.

6. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 5, **dadurch gekennzeichnet,** daß auf einigen Bahnen die beugende Oberfläche eine Reihe von allgemein quer zur Bahn orientierten Kerben umfaßt und auf einigen Bahnen die beugende Oberfläche eine Reihe von allgemein entlang der Bahn orientierten Kerben umfaßt.

7. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 6, die Bahnen (10) enthält, die Kerben aufweisen, die allgemein in Längsrichtung der Bahnen periodisch wellenförmig sind.

8. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 7, die Bahnen (7) enthält, deren beugende Oberfläche Inseln (8) umfaßt, die Kerben aufweisen, die sich allgemein in Längsrichtung der Bahn erstrecken, wobei die Inseln von ebenen Gebieten (9) umgeben sind.

9. Eine diffraktive Vorrichtung nach Anspruch 8, **dadurch gekennzeichnet,** daß die ebenen Gebiete mit einer Mikroboschriftung (13) geprägt oder bedruckt sind.

10. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 9, **dadurch gekennzeichnet,** daß ein von der Vorrichtung erzeugtes Bild ein gleichförmiges bzw. blankes Bild ist, das durch physikalische Zerstörung oder Modifikation von Gebieten der beugenden Oberfläche auf ausgewählten Bahnen zum Erzeugen von entsprechenden diffus reflektierenden Gebieten mit Bildinformation verschlüsselt werden kann.

11. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 10, **dadurch gekennzeichnet,** daß auf einigen Bahnen die beugende Oberfläche ein Muster aus Parallelogrammen (18) mit variierenden Winkelorientierungen umfaßt, die in der Bahnoberfläche verzahnt sind.

12. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 11, **dadurch gekennzeichnet**, daß Teile der beugenden Oberflächen auf einigen Bahnen zur Erzeugung von Graustufen-Bildinformationen in der Bildebene bestimmt sind.

13. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 12, **dadurch gekennzeichnet**, daß Teile der beugenden Oberflächen auf einigen Bahnen zum Erzeugen von Farbeffekten in der Bildebene bestimmt sind.

14. Eine diffraktive Vorrichtung nach Anspruch 13, **dadurch gekennzeichnet**, daß die Farbeffekte sich entlang eines Weges in der Bildebene zu bewegen scheinen, wenn die Vorrichtung um eine Achse in ihrer eigenen Ebene gedreht wird.

15. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 14, **dadurch gekennzeichnet**, daß Bildinformationen von einem durch die Vorrichtung erzeugten Bild in analoger Weise entlang der Länge einiger Bahnen erzeugt werden, wobei jede Bahn eine Linie des Bildes erzeugt und die durch diese Bahnen erzeugten Linien in Kombination das Bild bilden.

16. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 15, **dadurch gekennzeichnet**, daß Bildinformationen von einem durch die Vorrichtung erzeugten Bild in digitaler Weise entlang der Länge einiger Bahnen erzeugt werden, wobei jede Bahn eine Linie des Bildes erzeugt und die durch diese Bahnen erzeugten Linien in Kombination das Bild bilden.

17. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 16, **dadurch gekennzeichnet**, daß einige Bahnen diffus reflektierende Gebiete einschließen.

18. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 17, **dadurch gekennzeichnet**; daß einige Bahnen spiegelnd reflektierende Gebiete einschließen.

19. Eine diffraktive Vorrichtung nach irgendeinem der Ansprüche 1 bis 18, **dadurch gekennzeichnet**, daß die Variationen in der Orientierung, Krümmung und Beabstandung durch mathematische Funktionen zweier Variablen beschrieben werden können, in denen die Hessesche der zweiten Ableitungen außer entlang gewisser charakteristischer Linien nicht Null ist.

**Revendications**

1. Dispositif de diffraction comportant une structure de surface en relief qui, lorsqu'elle est illuminée par une source lumineuse, engendre une ou plusieurs images de diffraction qu'il est possible d'observer depuis des plages d'angles d'observation particulières autour du dispositif, dans lequel une partie au moins de la structure de surface en relief est agencée dans une série de pistes (11, 12), chaque piste comportant une structure de surface en relief qui comprend des éléments de structure individuels (18), ladite structure de surface en relief étant continue à l'intérieur de la piste en ce qu'il n'existe pas de différence substantielle entre des éléments de structure adjacents en termes d'orientation, de courbure et d'espacement et de telle sorte que des effets de diffraction incidents dus à des discontinuités autour de la bordure d'une piste sont diminués le long de la longueur de la piste, mais la structure de surface en relief étant discontinue vis-à-vis des pistes adjacentes (11, 12) en ce qu'il existe des différences substantielles entre des éléments de structure adjacents en termes d'orientation, de courbure ou d'espacement, chaque piste ayant une longueur supérieure à 0,5 mm, chaque piste ayant une largeur inférieure à 0,26 mm, et chaque piste ayant une surface de diffraction qui engendre une composante d'une image de diffraction, telle que l'une au moins des images de diffraction engendrées par le dispositif de diffraction est formée de composantes d'image engendrées par une pluralité des pistes, et dans lequel certaines au moins desdites pistes ont des rainures de diffraction ou d'autres formes (18) sur leurs surfaces, qui varient en continu en termes d'orientation, de courbure et/ou d'espacement le long de la piste, lesdites variations d'orientation, de courbure et/ou d'espacement étant des moyens grâce auquel des informations d'image sont codées à l'intérieur des pistes.

2. Dispositif de diffraction selon la revendication 1, dans lequel les pistes sont droites et parallèles.

3. Dispositif de diffraction selon la revendication 1, dans lequel les pistes forment des zones de cercles concentriques.

4. Dispositif de diffraction selon la revendication 1, dans lequel les pistes ont la forme de lignes incurvées.

5. Dispositif de diffraction selon l'une quelconque des revendications 1 à 4, dans lequel une région de la structure de surface en relief engendre deux images de diffraction différentes qu'il est possible d'observer depuis des plages d'angles d'observation différentes, et un premier groupe de pistes sur la région engendre l'une des images de diffraction, et un deuxième groupe de pistes entremêlées avec le premier groupe engendre l'autre image de diffraction.

6. Dispositif de diffraction selon l'une quelconque des revendications 1 à 5, dans lequel sur certaines pistes (11) la surface de diffraction comprend une série de rainures orientées généralement à travers la piste, et sur certaines pistes (12) la surface de diffraction comprend une série de rainures orientées généralement le long de la piste.

7. Dispositif de diffraction selon l'une quelconque des revendications 1 à 6, qui inclut des pistes (10) possédant des rainures qui ondulent périodiquement généralement dans le sens de la longueur des pistes.

8. Dispositif de diffraction selon l'une quelconque des revendications 1 à 7, qui inclut des pistes (7) dont la surface de diffraction comprend des îlots (8) qui ont des rainures s'étendant généralement dans le sens de la longueur des pistes, les îlots étant entourés par des régions planes (9).

9. Dispositif de diffraction selon l'une quelconque des revendications 1 à 8, dans lequel les régions planes sont matricées ou imprimées par microécriture (13).

10. Dispositif de diffraction selon l'une quelconque des revendications 1 à 9, dans lequel une image engendrée par le dispositif est une image uniforme, ou une image vierge qui peut être codée avec des informations d'image par destruction physique ou modification de régions de la surface de diffraction sur des pistes choisies pour produire des régions correspondantes qui présentent une réflexion diffuse.

11. Dispositif de diffraction selon l'une quelconque des revendications 1 à 10, dans lequel sur certaines pistes la surface de diffraction comprend un motif de parallélogrammes (18) avec des orientations angulaires variables, en creux dans la surface de la piste.

12. Dispositif de diffraction selon l'une quelconque des revendications 1 à 11, dans lequel des parties des surfaces de diffraction sur certaines pistes sont dévolues à la génération d'informations d'image avec échelle de gris dans le plan image.

13. Dispositif de diffraction selon l'une quelconque des revendications 1 à 12, dans lequel des parties des surfaces de diffraction sur certaines pistes sont dévolues à la génération d'effets de couleur dans le plan image.

14. Dispositif de diffraction selon la revendication 13, dans lequel les effets de couleur semblent se déplacer le long d'un trajet dans le plan image lorsque l'on fait basculer le dispositif autour d'un axe dans son propre plan.

15. Dispositif de diffraction selon l'une quelconque des revendications 1 à 14, dans lequel les informations d'image dans une image engendrée par le dispositif sont codées d'une manière analogique le long de la longueur de certaines pistes, chaque piste engendrant une ligne de l'image, et les lignes engendrées par ces pistes se combinant pour former l'image.

16. Dispositif de diffraction selon l'une quelconque des revendications 1 à 15, dans lequel les informations d'image dans une image engendrée par le dispositif sont codées d'une manière numérique le long de la longueur de certaines pistes, chaque piste engendrant une ligne de l'image, et les lignes engendrées par ces pistes se combinant pour former l'image.

17. Dispositif de diffraction selon l'une quelconque des revendications 1 à 16, dans lequel certaines pistes incluent des régions présentant une réflexion diffuse.

18. Dispositif de diffraction selon l'une quelconque des revendications 1 à 17, dans lequel certaines des pistes incluent des régions présentant une réflexion spéculaire.

19. Dispositif de diffraction selon l'une quelconque des revendications 1 à 18, dans lequel les variations d'orientation,

de courbure et d'espacement peuvent être décrites par des fonctions mathématiques à deux variables dans lesquelles le Hessian des dérivées secondes est non-évanouissant, excepté le long de certaines lignes caractéristiques à l'intérieur de chaque piste.

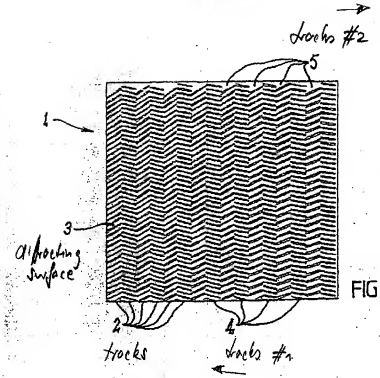



FIG 1

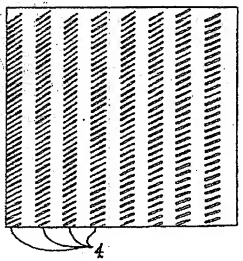



FIG 2

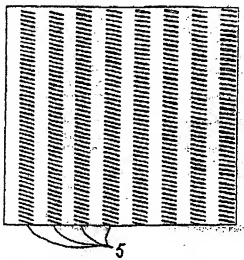
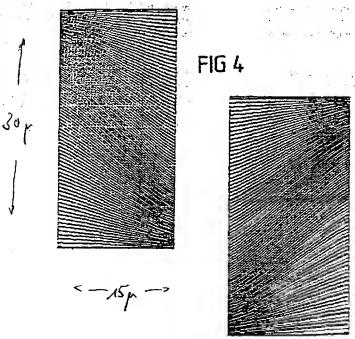



FIG 3

"Segmente"

FIG 4



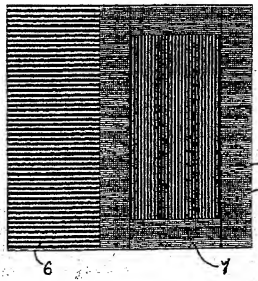



FIG 5


FIG 6


FIG 7

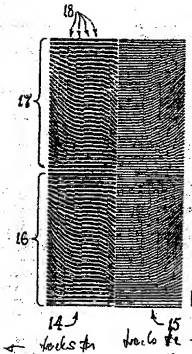



FIG 8

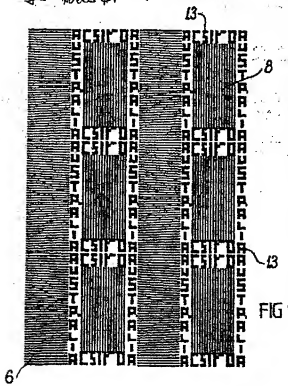



FIG 9

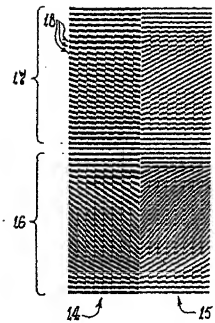



FIG 10

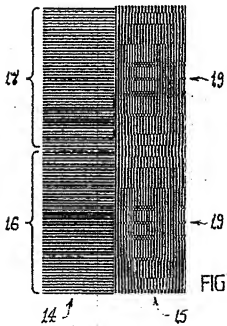



FIG 11